A STRUCTURAL AND CHEMICAL DESCRIPTION OF LITTER AND HUMUS IN A MATURE SCOTS PINE STAND

Håkan Staaf and Björn Berg

Department of Plant Ecology, University of Lund, Lund, Sweden, and Department of Microbiology, Swedish University of Agricultural Sciences, Uppsala, Sweden

Abstract

Samplings of the L-, FH-layers and mineral soil layers were carried out in the mature Scots pine stand at Ivantjärnsheden. The L-layer samples were sorted into different litter components and live roots were removed from the FH-layer samples. Analyses were thereafter made for carbon and the nutrients nitrogen, phosphorus, potassium, sodium, calcium, magnesium and sulphur. Analysis of organic components concerned water- and acetone soluble substances, Klason lignin, cellulose and hemicelluloses. The mineral soil samples were analysed for carbon and nitrogen. Total amounts of different litters and humus as well as total amounts of nutrients were calculated for the L- and FH-layers, and mineral soil layers of 0-10 cm, 10-20 cm, 20-30 cm depth and bleach soil in the stand.

1. Introduction

A chemical and morphological description of the organic matter in soil and litter is a necessary basis for the study of soil processes. Both quantitative and qualitative data are needed as state variables in nutrient models and tree growth models in the present project.

Consequently, a static description of ground litter and humus was made in the mature pine stand, Ih VA, at the SWECON research site at Ivantjärnsheden, Jädraås. Two samplings were made during 1974-75 for both structural and chemical analysis of the different soil horizons.

The most intensive structural division of the material was made in the litter layer. The relatively rapid turn-over of organic matter in this layer makes it probable that the total amount of macronutrients cannot be considered constant throughout one year, such estimates thus have to be properly specified in time. In deeper soil layers the relationships are probably more constant, at least considering total amounts of carbon and nitrogen, and the present estimates from the mineral soil are considered valid for a period of several years.

The root litter component is being treated in a separate investigation, the results of which will be reported elsewhere.

Site vegetation has been described earlier by Bråkenhielm (1975). The elemental composition of the mineral particles and exchangeable amounts of cations in the soil profile have been examined by Bringmark & Petersson (1975). Jansson (1977) has given data on physical properties of the soil profiles at Ivantjärnsheden.

2. Materials and methods

2.1 Soil morphology

Podsolic soil profiles are typical of the Ivantjärnsheden area. An iron podsol (Kubiëna, 1953) with a fairly weakly developed bleached layer (2-7 cm) is present in the mature pine stand, Ih VA. The humus type is a typical mor and the litter layer very loose with living mosses and lichens entangled into it. The most easily distinguished morphological level is the one between the humus (FH) layer and the mineral soil, on top of the A_1 horizon, which is considered as the zero level in the soil profile. Charcoal is often found in the humus layer and the upper part of the mineral soil. The following soil layers have been used as sampling units:

	Our denotation	Denotation according to Kubiëna (1953)
Litter layer	L layer	A_{00}
Humus layer	FH layer	A_{01}-A_{02}
Mineral soil 1-10 cm	Min $_{1-10}$	A_1-A_2/B
Mineral soil 10-20 cm	Min_{10-20}	B
Mineral soil 20-30 cm	Min_{20-30}	B/C
Bleached layer	Bleached layer	A_2

The bleached layer samples were collected as a complement to the mineral soil 0-10 cm horizon, of which it constitutes the upper part.

2.2 Samplings

2.2.1 Litter layer

Two samplings were made; one during the second week of May 1974, denoted S 1, and one during the first week of September 1975, denoted S 2. The former was an estimate of the amount and chemical composition of litter at the very start of the vegetation period. The latter sampling was made when the litter layer was assumed to have its minimum bulk, just before the start of the autumn needle litter fall period.

The samples were taken on an areal basis in a randomized block area of 100 x 200 m (Fig. 1). Iron rings were pressed down into the soil; all material from each soil layer within them was collected by hand and put into paper bags. Fifteen samples of 0.25 m^2 were taken in S 1 and 24 samples of 0.071 m^2 in S 2, totally representing about 0.19 $^o/oo$ and 0.09 $^o/oo$ respectively of the site area. Sampling areas which coincided with a tree stem were omitted.

The litter samples were dried in the paper bags at room temperature and stored as such until the assortment work could start.

2.2.2 Humus layer

Twenty-four samples of 0.071 m^2 each were taken in the S 2 sampling on identical areas and with the same technique as for the litter layer.

The iron rings were kept in the soil while the sampling was made. Great care was taken to identify the boundary line to the mineral soil.

2.2.3 Mineral soil

The bleached layer was sampled in May 1976 on the S 2 plots. Twenty-four samples were taken and the same technique as for the litter and humus layers was used. The soil was carefully collected with plastic spoons and stored in paper bags.

The mineral soil from 0-10 cm and 10-20 cm depth was sampled within the scope of an investigation on nitrogen mineralization (Popovic 1976). Twelve independent estimates were made in the period 1974-75. The values presented were calculated from this data.

No samples were taken from 20-30 cm depth in the mineral soil layer. The values for that layer were estimated by combining data from the 0-10 and 10-20 cm soil layers and from data presented by Bringmark & Petersson (1975).

2.4 Structural description of the soil layers

2.4.1 Litter layer

Each sample was sorted into the following structural litter components:

a. pine needles
b. pine bark
c. pine twigs > 5 mm diameter
d. pine twigs < 5 mm diameter
e. pine cones
f. cowberry leaves
g. heather litter (includes woody stems, long and short shoots and capsules)
h. moss litter
j. miscellaneous (rest fraction)

All components were weighed individually (accuracy ± 0.0005 g) after drying at 85^{o}C.

The amount of moss litter in each sample was estimated from the total weight of living and dead; the latter weight derived from subsamples that were fractioned into living and attached dead. Green parts were considered as living.

The miscellaneous fraction contained:

i, litter fractions not included in a-h, namely lichen litter and male flowers of pine
ii, identifiable but very small fragments of fractions a-h
iii, small non-identifiable particles, which could be regarded as humus.

The delimitation of the fraction was based on practical considerations determined by the time available for assortment.

2.4.2 Humus layer

Living roots with attached dead parts were separated from the humus material while still in a fresh condition. The remaining fraction was then sorted into humus and charcoal, dried at 85°C and weighed. The distinction between root litter pieces and humus is difficult and time-consuming to perform, which means that a certain amount of root litter might have been included in the humus fraction.

Loss on ignition (LOI) was determined on all humus samples after heating dried material for 2 hours at 600°C. The humus content was considered identical with LOI in this soil layer.

2.4.3 Mineral soil

The bleached layer samples were sieved through 6 mm mesh in order to remove all living roots and attached dead. After drying at 105°C and weighing the mean areal weight was calculated.

The mineral soil samples Min_{0-10} and Min_{10-20} cm were likewise sieved and living and dead roots removed (see Popovic 1975). The mean weight of three composite samples, each representing the whole sampling area, from each of the two samplings was used as one estimate of the areal weight.

LOI was determined on each composite sample in the same way as for the humus layer. Humus content was estimated from total carbon content in per cent multiplied by $\frac{1}{0.58}$ (Troedsson & Nykvist 1973).

2.5 Chemical analysis

2.5.1 Elemental composition

The litter and humus layer samples from S 1 and S 2 respectively were randomly pooled to five composite samples for each structural fraction Fig. 2). To obtain a good representation of the chemical composition the composite samples were made up of constant weight fractions of the subsamples. Analyses were performed as duplicates on all fractions from the litter layer, from the S 2 humus layer and the mineral soil layers. The bleached layer samples were analyzed for total-C and the mineral soil for total-C and total-N; all other samples were analyzed according to the list below.

The following analytical techniques were used:

total-C: wet oxidation according to Nömmik (1971)
total-N: traditional semi-micro Kjeldahl procedure

After acid wet oxidation in HNO_2+$HClO_4$

total-S: analyzed as Ba SO_4-precipitate with a turbidimetric procedure (Blanchar et al. 1965)
total-P: vanadate yellow-complex method (Jackson 1958)
total-Na: flame photometry
total-Ca, Mg: atomic adsorption spectrophotometry in 1% LaCl-solution (Pawluk 1967)

2.5.2 Organic components

Analyses were made on one composite sample for each structural component except for needle litter, all samples of which were analyzed individually. Single analyses were used, and performed on dried (85^{o}C) and milled samples (particle size < 0.5 mm diameter).

The amounts of water soluble and acetone soluble substances were extracted by sonication of the milled material. The extracted material was determined for Klason lignin and acid soluble lignin with spectrophotometry (Schöning & Johansson 1965).

The cellulose and hemicelluloses were determined by gas chromatography as acetyl derivates of the mono sugars after hydrolysis (Bethge, Rådeström & Theander 1971).

2.6 Calculations and statistical treatment

All calculations on chemical and morphological components of the organic parts of the soil layers were made on an areal basis and expressed as g/m^2 or kg/m^2. Absolute concentrations and percentages of the chemical components based on dry weight have also been given.

In the structural description of the L, FH, and bleached layers mean values for sample weights were used for the calculation of areal weights of litter and humus components. The sampling procedure selected for the L and FH layers means that non-normal distribution of sample weights might occur. The normality was therefore judged from frequence distribution histograms as well as from coefficients of skewness (Snedecor & Cochran 1956). Approximate normality was assumed when no significant skewness could be confirmed on the 1% significance level. In such cases mean values were given with 95% confidence limits, otherwise not.

For the mineral soil, mean values of total weight of pooled samples divided by total sampling area for each sampling made up one estimate. On the assumption that constant conditions prevailed for these soil characters, repeated samplings of this type were made during the two years and the results can be considered as separate and independent estimates of the same attribute. This procedure yields very few samples for analysis but is very accurate for quantitative determinations of chemical composition in forest floors (Falk 1973). The results can then easily be treated with traditional statistical methods since the mean weights tend to be normally distributed, even though they have been obtained from subsamples with non-normal distribution (Bailey 1959).

Parallel samples for inorganic analysis were obtained by a random combination of subsamples, and were considered as equivalent to separate independent samples representing the whole stand. Consequently, mean values and confidence limits have been given for the elements that the samples were analysed for.

Only one sample of each structural component was analysed for its organic composition, the result forming a weighted mean of the whole sample. The area amounts therefore include the same statistical errors as in the structural analysis.

3. Results and discussion

3.1 Structural description

Most of the litter components in the L layer had similar amounts in the two samplings (Table 1). There were great differences though, between S 1 and S 2 for litter types with a heavily skewed weight distribution (e.g. cones and pine twigs) while very good agreement was found for needles and bark as well as for the total layer sums. The moss litter figures can be considered as fairly uncertain owing to a large spatial variability and to difficulty in defining the moss litter structurally, while the fairly high differences for heather litter cannot be explained.

A significant skewness in the spatial weight distribution was found for pine twigs, cones, and the miscellaneous litter fraction in both S 1 and S 2, and for cowberry leaves in S 2. The confidence limit values for these fractions cannot therefore be considered as very reliable. From Table 1 and Figure 3 it is clear that almost all other litter fractions, as well as the figures for the whole soil layers, were slightly skewed towards low values.

The amount of litter present on small areas of the forest floor is dependent on both input of material and decomposition rates. There are no differences in decomposition rates for needle litter between sampling areas of the size used in this investigation (Berg, in manuscript), and it is reasonable to assume the same behaviour for other litter fractions. Data on the spatial distribution of litter fall would give valuable information on specific sampling areas with high litter input but it

seems probable that litter fractions like cones and twigs are associated with areas near trees and seldom fall on more distant areas. On the other hand, no significant correlation between amounts of any litter type and distance from the nearest tree could be found in the present material. Both linear and logarithmically transformed distances were tested. Similarly, low degrees of significance were obtained from Student's t-test on the difference between plots > 2 m and < 2 m from the nearest tree, when the S 2 material was grouped into these two strata. For all types of pine litter the mean values were higher in the < 2 m stratum but in no case were they significantly different ($p > 0.05$) from the > 2 m one. This, together with the fact that exceptionally large amounts of litter could be found in the L layer at any distance from the present trees, indicates a complex litter fall regime and decomposition relations on the soil floor.

The total amounts of organic matter in the different soil layers are presented in Table 2. Note the large amount stored in the mineral soil, about threefold that in the FH layer and sevenfold that in the litter layer.

The bleached layer was fully included in the samplings of the first 10 cm of the mineral soil, but the samples for its weight determination were not taken in the same monoliths as the rest of the mineral soil but together with the L and FH layer samples. Accurate figures for the sum of the whole soil profile can thus only be obtained if the same upper limitations of the bleached layer can be distinguished reproducibly in the two sampling sets. One source of error could be a tendency to place the delimitation somewhat higher in the large top soil samples than in the small-diameter mineral soil monoliths, where it is easier to remove all traces of the humus layer. This results in a certain overestimation of the organic content of the bleached soil horizon, a corresponding underestimation of the organic content of the FH layer, and probably a very small underestimation of the total amount of organic matter in the whole soil profile.

A test was also made of the relation between the sizes of the different soil layers on the individual sampling plots of S 2. No significant weight correlations were found between the L, FH, and bleached layers. This could have been expected as the soil layers are likely to have completely different time aspects on their development. A steady state situation between the soil layers on small sampling areas will probably not occur in a forest stand because of the frequent structure change of the vegetation, with or without the influence of man.

The classification into sampling plots < 2 m and > 2 m from the nearest tree gave no significant weight differences for the two strata when applied to the different soil layers. When sampling plots < 2 m from the nearest individual of the youngest stump generation were added to the > 2 m stratum, this resulted in significantly higher weight values for the FH layer than the < 2 m one. Consequently, it appears that trees cut down in 1960 have an influence on the present size of the FH layer of Ih VA.

3.2 Chemical description

3.2.1 Elemental composition

No significant difference between S 1 and S 2 could be found for the total amounts of any element in the L layer (Table 4 and 5). The distribution of nutrients between different litter structures could of course be influenced by the same errors as mentioned above (Paragraph 3.1) and small deviations in this respect between S 1 and S 2 should not be overemphasized. However, some remarks are justified:

- Cowberry leaves had higher concentrations of most elements in S 1 (Table 3). The differences for nitrogen, phosphorus and calcium were of such a magnitude that there might be different decomposition levels of dead leaves of the two samplings.
- Both total amounts and concentrations of nitrogen were higher in S 2 than in S 1 (Tables 3, 4 and 5), a probable explanation being that more needle litter was present on the forest floor in spring after the autumn and spring litter fall peaks than in early September. An increase in the absolute amounts of nitrogen is known to occur during the first 18 months of needle litter decomposition (Staaf & Berg 1977), which would explain the higher nitrogen concentration in the S 2 samples.

With the exception of potassium, the variations in sample weights was greater than the variation between the nutrient concentrations (Table 13). The uncertainty of the total amounts of the element was thus mainly dependent on the wide differences among samples.

The pooling of S 1 samples had little influence on the standard errors of mean for weights and total element amounts in needle litter (Table 12) while a reduction of the area sampled, as represented by S 2, increased the standard errors considerably. A comparison of needle litter data in Tables 12 and 13 exemplifies this.

The dislocation of total amounts of carbon and nitrogen towards the mineral soil (Table 7) was more obvious than that for organic matter. The carbon and nitrogen contents of the organic matter increased with depth in the soil profile and the C/N-ratio decreased from 49 in the L layer to 25 in the lowest mineral soil horizon.

The figures given in Tables 6 and 7 not only include the amounts in the solid organic phase but also adsorbed ions and ions in the soil water solution. Only very small amounts of nitrogen (< 1%) of the total amount were found to be extractable (Popovic 1976), but about 10% of the phosphorus in the FH layer is soluble in 1% acetic acid (Sohlenius et al. 1976). Bringmark & Petersson (1975) report that the extractable parts (in 1 M NH_4 Cl) of the total amounts in the FH layer nutrients were about 70% for Ca, 50% for Mg and 30% for Na and K. In the litter layer the extractable shares probably are considerably lower.

3.2.2 Organic composition

There were some differences in chemical composition among the structural litter components. The percentages of water soluble and acetone soluble substances were low and rather variable, but there was a clear difference between the samplings (Tables 8 and 10) with almost doubled levels in the September sampling (S2). The concentration of water soluble substances varies considerably in litter under decomposition (Berg, to be published). It is possible that the water soluble fractions may act as a substrate pool for microorganisms, its size perhaps varying during the year.

The Klason lignin contents of the analysed components were higher than in the corresponding undecomposed litters. Lignin is decomposed slower than the other chemical components of the litter (Berg, to be published). There was a higher level of lignin in the needles in the September sampling than in that in May (Tables 8 and 10). The main needle litter-fall occurs in September - October (Flower-Ellis, pers. comm.) and the needles have a lignin concentration of about 23 per cent. These needles decompose very little during the winter and the needle litter component in May will thus have a low lignin level which increases as the needles are decomposed during the summer.

The levels of cellulose and hemicelluloses were highest in the May sampling and as they are decomposed faster than lignin (Berg, to be published) the percentage decreased during the summer and was slightly lower in the September sampling (Tables 8 and 10). Comparison of the samplings appears to be a reasonable procedure for needle litter with its fairly distinct litter fall whereas most of the other fractions could not be compared in this way. The low percentage of Klason lignin in the large humus component appears to contradict the earlier statement about slow lignin decomposition and a rather high percentage of lignin might have been expected. It is difficult to interpret the differences between the samplings for all the analyzed components, but a rough comparison between total levels of polymer carbohydrates showed the opposite result to lignin for the needle litter, giving a level that was lower in September than in May.

It is somewhat surprising that the humus fraction had such a high concentration of cellulose - a fraction that might be expected to decompose more readily than lignin. Comparison of the lignin contents of litter and humus (Tables 8 and 10) shows that much more lignin than cellulose had disappeared during the humification process. No reasonable explanation has yet been found. It should be remembered, though, that root litter, which gives a large input to humus (Staaf & Berg, 1977), is not included in the present investigation. A calculation of different litters and their decomposition rates might well reveal the origins of the humus and thus provide an explanation to this problem.

4. Literature

BAILEY, N.T.J. 1959. Statistical methods in biology. The English Universities Press LTD. London. 198 pp.

BETHGE, P.O., RÅDESTRÖM & R., THEANDER, O. 1971. Kvantitativ kolhydratbestämning - en detaljstudie. Svenska träforskningsinstitutet. Meddelande nr 63 serie B. Stockholm.

BLANCHAR, R.W. et al. 1965. Determination of sulphur in plant materials by digestion with nitric and perchloric acid. Soil Sci. Soc. Am. Proc. 29, 71-72.

BRINGMARK, L. & PETERSSON, G. 1975. Studier av kemiska markvariabler i en 120-årig tallskog på sand. Swed. Con. For. Proj. Int. Rep. 27. 40 pp.

BRÅKENHIELM, S. 1975. Ivantjärnshedens vegetation. Swed. Con. For. Proj. Int. Rep. 18. 51 pp.

FALK, J. 1972. En metod för bestämning av humusskiktets innehåll av växtnäringsämnen. Inst. för skogsskötsel. Rapporter och uppsatser nr 1. 1973. Stockholm. 130 pp.

JACKSON, M.L. 1958. Soil chemical analysis. Prentice-Hall INC. London.

JANSSON, P-E. 1977. Jordmåns- och markbeskrivning för Ivantjärnsheden. Swed. Con. For. Proj. Int. Rep. 54. 66 pp.

KUBIËNA, W.L. 1953. Bestimmungsbuch und Systematik der Böden Europas. Ferdinand Enke Verlag. Stuttgart. 392 pp.

NÖMMIK, H. 1971. A modified procedure for determination of organic carbon in soils by wet combustion. Soil Sci. 111, 330-336

PAWLUK, S. 1967. Soil analysis by atomic absorption Spectrophotometry. Atomic Absorption Newsletter 6, 53-56.

PERSSON, H. 1975. Dry matter production of dwarf shrubs, mosses and lichens in some Scots pine stands at Ivantjärnsheden, Central Sweden. Swed. Con. For. Proj. Techn. Rep. 2. 25 pp.

POPOVIC, B. 1976. Kvävemineralisering i ett äldre tallbestånd. Swed. Con. For. Proj. Int. Rep. 35. 16 pp.

SCHÖNING, A. & JOHANSSON, G. 1965. Adsorbtiometric determination of acid-soluble lignin in semichemical bisulphite pulps and in some woods and plants. Swedish Paper Journal 68, 607.

SNEDECOR, G.W. & COCHRAN, W.G. 1967. Statistical methods. Sixth ed. Iowa State University Press. 393 pp.

STAAF, H. & BERG, B. 1977. Mobilization of plant nutrients in a Scots pine forest mor in Central Sweden. Silva Fennica, in press.

SOHLENIUS, B. et al. 1976. Mineralisering och organismaktivitet i en barrskogshumus - ett modellbyggnadsförsök. Swed. Con. For. Proj. Int. Rep. 40. 51 pp.

TROEDSSON, T. & NYKVIST, N. 1973. Marklära och markvård. Almqvist & Wiksell. Stockholm. 402 pp.

Table 1. Structural composition of the litter (L) layer at Ih VA as determined from two samplings; S 1 from mid-May 1974 and S 2 from early September 1975. Mean values are given with 95% confidence limits (CL). The degree of normality in the material is indicated by the coefficient of skewness (g_1), the significance of which was tested from tables of t distribution.

Litter fraction	May sampling (S 1)					September sampling (S 2)				
	Areal weight (g/m^2) $\bar{x}$	95% CL	Coeff. of skewness (g_1)	Relative composition (%)	n	Areal weight (g/m^2) $\bar{x}$	95% CL	Coeff. of skewness (g_1)	Relative composition (%)	n
Needles	156	16	+0.04	22	15	149	27	+0.82	21	24
Bark	63	10	+0.69	9	"	59	9	+0.87	8	"
Pine twigs > 5 mm Ø	24	20	$+2.76^{***}$	3	"	9	5	$+1.35^{**}$	1	"
Pine twigs < 5 mm Ø	52	13	+0.77	7	"	25	10	$+2.64^{***}$	4	"
Cones	26	19	$+1.88^{**}$	4	"	45	24	$+1.43^{**}$	6	"
Cowberry leaves	25	6	+0.85	4	"	30	9	$+0.96^{*}$	4	"
Heather litter	75	18	-0.05	11	"	55	13	+0.55	8	"
Moss litter	68	15	+0.07	10	"	86	30	+0.41	12	"
Miscellaneous	208	66	$+1.58^{*}$	30	"	259	53	$+1.36^{**}$	36	"
Total L layer	697	103	+0.38	100	"	715	98	+0.89	100	"

* significant skewness $0.05 > p > 0.01$

** significant skewness $0.010 > p > 0.001$

*** significant skewness $p < 0.001$

Table 2. Some data on the structural composition of the FH and mineral soil layers at Ih VA. The bleached horizon constitutes the upper part of the mineral soil 0-10 cm and was fully included in the latter. The significance level of the coefficient of skewness is given from tables of t distribution.

Soil layers		Total areal weight (kg/m^2) $\bar{x}$	± 95% CL	Coeff. of skewness (g_1)	Organic content (kg/m^2) $\bar{x}$	± 95% CL	(%of dw)	Loss on ignition (% of dw) $\bar{x}$	± 95% CL	n	Sampling
FH layer	Charcoal	0.005	0.005	+3.11***						24	Sept, 1975
	Humus	1.99	0.26	0.50	1.54	0.21	77.3	77.3	4.6	24	Sept, 1975
Mineral	0 - 10 cm	99.4	1.9		2.54	0.19	2.6	3.6	0.3	12	May, 1974
soil	10 - 20 cm	121	2.3		1.75	0.08	1.5	2.8	0.2	12	
	20 - 30 cm[1)]	130			0.5		0.4	1.4			Oct, 1975
	Total	350			4.8						
Bleached layer	Total	21.4	3.9	0.08	0.8		3.6	5.6	1.3	24	June, 1975

1) estimated values based on Bringmark & Petersson (1975) and figures from the present report

xxx significant skewness $p < 0.001$

Table 3. Concentrations of some nutrients in different litter components of the L layer of Ih VA at two samplings, May 1974 (S1) and September 1975 (S2).

S1	Total concentration of nutrients (mg/g dw)						
	C	N	P	K	Na	Ca	Mg
Needles	506	5.1	0.51	0.85	0.061	4.65	0.35
Bark	501	6.0	0.43	0.58	0.060	4.43	0.28
Pine twigs							
> 5 mm Ø	470	3.7	0.18	0.29	0.042	1.42	0.12
< 5 mm Ø	507	7.4	0.38	0.65	0.050	3.01	0.23
Cones	480	4.8	0.34	0.35	0.022	0.85	0.20
Cowberry leaves	519	14.5	0.98	1.11	0.060	5.67	0.48
Heather litter	500	10.7	0.63	1.10	0.064	3.09	0.35
Moss litter	454	9.8	0.79	3.05	0.075	3.18	0.49
Miscellaneous	481	11.4	0.81	1.25	0.080	3.30	0.43

S2	Total concentration of nutrients (mg/g dw)							
	C	N	P	K	Na	Ca	Mg	S
Needles	505	8.7	0.53	0.86	0.057	3.45	0.34	0.53
Bark	492	6.6	0.32	0.53	0.048	3.61	0.27	0.46
Pine twigs								
> 5 mm Ø	515	5.8	0.24	0.38	0.031	1.61	0.15	0.41
< 5 mm Ø	508	7.2	0.36	0.48	0.045	2.36	0.20	0.63
Cones	490	3.7	0.21	0.33	0.017	0.53	0.14	0.29
Cowberry leaves	524	12.9	0.58	0.86	0.046	4.45	0.40	0.78
Heather litter	488	10.3	0.51	0.98	0.044	2.18	0.32	0.84
Moss litter	456	8.9	0.82	3.29	0.070	4.22	0.47	0.92
Miscellaneous	445	12.0	0.69	1.13	0.078	2.74	0.42	0.91

Table 4. Total amounts of nutrients in different litter components in the L layer of Ih VA in the S1 sampling (May 1974).

Litter fraction		Nutrient (g/m^2) C	N	(mg/m^2) P	K	Na	Ca	Mg
Needles	$\bar{X}$	79.1	0.79	79	132	9.5	726	54
	± 95% CL	8.0	0.09	9	19	1.3	79	6
Bark	$\bar{X}$	31.7	0.38	27	37	3.8	280	18
	± 95% CL	4.6	0.07	5	6	1.1	40	3
Pine twigs	$\bar{X}$	11.1	0.09	4.3	6.8	1.0	34	2.9
>5 mm Ø	± 95% CL	4.0	0.04	2.3	5.0	0.5	17	1.3
Pine twigs	$\bar{X}$	26.4	0.38	20	34	2.6	157	12
<5 mm Ø	± 95% CL	6.6	0.06	6	4	0.6	21	1
Cones	$\bar{X}$	10	0.11	7	7	4	18	4
	± 95% CL	11	0.12	8	8	5	2	5
Cowberry	$\bar{X}$	13.2	0.37	25	28	1.5	144	12
leaves	± 95% CL	1.9	0.04	3	7	0.5	29	3
Heather	$\bar{X}$	37.6	0.80	47	82	4.8	232	26
litter	± 95% CL	8.9	0.21	11	23	0.9	51	8
Moss	$\bar{X}$	30.7	0.67	53	206	5.1	215	33
litter	± 95% CL	4.9	0.05	11	32	1.3	46	5
Miscellaneous	$\bar{X}$	100	2.37	169	259	16.6	690	90
	± 95% CL	29	0.84	51	69	6.8	280	36
Total	$\bar{X}$	340	5.95	431	792	45	2490	253
L layer	± 95% CL	26	0.66	47	84	6	240	34

Table 5. Total amounts of nutrients in different litter components in the L layer of Ih VA in the S2 sampling (September 1975).

Litter fraction		Nutrient (g/m^2) C	N	(mg/m^2) P	K	Na	Ca	Mg	S
Needles	$\bar{X}$	75.3	1.29	79	129	8.6	514	50	79
	± 95% CL	25.5	0.54	27	21	3.2	127	15	37
Bark	$\bar{X}$	28.9	0.38	19	32	2.8	212	16	27
	± 95% CL	7.1	0.12	5	5	0.5	55	4	7
Pine twigs	$\bar{X}$	4.5	0.05	2.1	3.3	0.3	14	1.3	3.6
>5 mm Ø	± 95% CL	1.9	0.03	1.2	2.2	0.2	7	0.5	2.4
Pine twigs	$\bar{X}$	12.5	0.18	8.9	11.8	1.1	58	4.8	15
<5 mm Ø	± 95% CL	4.3	0.04	1.3	2.4	0.1	10	0.9	3
Cones	$\bar{X}$	21.4	0.17	9	14	0.7	23	6	12
	± 95% CL	9.5	0.07	4	6	0.3	10	3	5
Cowberry	$\bar{X}$	15.8	0.39	17	26	1.4	134	12	24
leaves	± 95% CL	5.6	0.17	7	7	0.6	46	4	10
Heather	$\bar{X}$	26.9	0.57	28	54	2.5	120	18	46
litter	± 95% CL	10.6	0.18	10	33	1.6	37	7	18
Moss	$\bar{X}$	39.0	0.76	70	282	6.0	361	40	78
litter	± 95% CL	13.7	0.19	10	104	2.0	206	12	23
Miscellaneous	$\bar{X}$	115	3.12	180	291	20	708	108	236
	± 95% CL	19	0.46	45	117	11	216	45	58
Total	$\bar{X}$	339	6.91	414	846	43	2140	257	521
L layer	± 95% CL	16	1.03	61	189	14	340	53	75

Table 6. Total amounts of nutrients in the L and FH layers of Ih VA at the S2 sampling (September 1975). All values are expressed in g/m^2. The L layer figures are taken from Table 7.

Soil layer		Nutrient (g/m^2) P	K	Na	Ca	Mg	S
L layer	$\bar{X}$	0.41	0.85	0.04	2.14	0.26	0.52
	95 % CL	0.06	0.19	0.01	0.34	0.05	0.08
FH layer	$\bar{X}$	1.07	1.85	0.20	4.57	1.12	1.54
	95 % CL	0.18	0.36	0.02	0.44	0.16	0.22

Table 7. Total amounts of carbon and nitrogen in different soil layers at Ih VA. Values are in g/m^2. L and FH layers represent the amounts of the S2 sampling (September 1975) and the mineral soil values are means for samplings in the period 1974-75.

	Carbon (g/m^2)			Nitrogen (g/m^2)		
	$\bar{X}$	± 95% CL	% of total soil horizon	$\bar{X}$	± 95% CL	% of total soil horizon
L layer	339	16	9	6.9	1.0	6
FH layer	687	110	18	16.2	3.0	14
Min soil[1)]						
0-10 cm	1470	110	39	42	1	37
10-20 cm	1010	49	26	36	2	32
20-30 cm	300		8	12		11
Total	3806			113.1		100

1) Calculated from Popovic (1976)

Table 8. Organic composition of the different litter componentsin the L and FH layers at Ih VA. Sampling in May 1974 (S1). The values are given in per cent.

	Water soluble	Acetone soluble	Klason lignin	Total lignin[1]	Cellulose	Mannan	Xylan	Galactan	Araban	Rhamnan	Total
L layer											
Needles	2.1	10.8	31.4	33.0	28.5	8.5	3.0	4.3	2.7	0.5	100
Bark	4.1	3.1	44.3	45.5	21.9	4.2	7.3	6.9	6.8	0.3	100
Pine twigs											
> 5 mm Ø	2.4	4.8	39.1	39.8	29.3	5.7	6.2	6.8	3.5	0.7	100
< 5 mm Ø	3.4	6.2	43.5	44.7	26.6	4.1	7.4	4.6	2.6	0.5	100
Cones	3.2	3.5	32.8	33.6	35.2	14.5	4.3	3.2	2.4	0.2	100
Cowberry leaves	3.3	3.4	52.7	54.9	21.6	2.5	6.9	3.7	3.0	0.7	100
Heather litter	2.3	4.8	45.7	47.4	17.7	2.8	16.4	4.4	3.2	0.5	100
Moss litter	4.2	1.2	48.7	49.8	20.5	8.7	3.9	6.1	3.3	2.3	100
Miscellaneous	4.7	5.8	42.8	44.7	20.7	9.7	4.0	7.6	2.0	0.9	100
FH layer											
Ashfree fraction	5.5	6.2	27.0	28.8	36.6	7.4	5.4	5.9	2.9	1.2	100

1) Includes Klason lignin and acid soluble lignin

Table 9. Total amounts of some organic compounds in the L and FH layers at Ih VA. All figures are given in g/m^2. Sampling in May 1974 (S1)

	Water soluble	Acetone soluble	Klason lignin	Total lignin	Cellulose	Mannan	Xylan	Galactan	Araban	Rhamnan
L layer										
Needles	3.2	16.9	58.9	51.4	44.4	13.3	4.6	6.7	4.2	0.8
Bark	2.6	1.9	28.0	28.8	13.8	2.6	4.6	4.3	4.3	0.2
Pine twigs										
> 5 mm Ø	0.6	1.1	8.9	9.1	6.7	1.3	1.4	1.6	0.8	0.2
< 5 mm Ø	1.8	3.3	22.9	23.6	14.0	2.2	3.9	2.4	1.4	0.2
Cones	0.8	0.9	8.4	8.6	9.0	3.7	1.1	0.8	0.6	0.0
Cowberry leaves	0.8	0.9	13.5	14.1	5.5	0.6	1.8	1.0	0.8	0.2
Heather leaves	1.8	3.6	34.3	35.6	13.3	2.1	12.3	3.3	2.4	0.4
Moss litter	2.9	0.8	33.1	33.9	13.9	5.9	2.7	4.1	2.2	1.6
Miscellaneous	9.8	12.1	95.0	98.5	43.0	20.1	8.3	15.8	4.1	1.8
Total L layer	24.3	41.5	293.0	303.6	163.6	51.8	40.7	40.0	20.8	4.8
FH layer										
Total	73	90	659	688	318	149	61	117	30	13

Table 10. Organic chemical composition of the different litter components in the L and FH layers at Ih VA. Sampling in September 1975 (S2). The values are given in per cent.

	Water soluble	Acetone soluble	Klason lignin	Cellulose	Mannan	Xylan	Galactan	Araban	Rhamnan
L layer									
Needles	7.2	9.0	37.5	26.9	7.7	3.3	3.7	3.2	1.6
Bark	4.7	3.3	44.7	22.6	4.2	6.9	5.7	7.2	0.7
Pine twigs									
>5 mm Ø	4.6	5.6	44.5	27.1	4.1	6.7	5.0	2.0	0.4
<5 mm Ø	4.2	7.1	44.4	22.1	6.7	6.5	5.0	3.3	0.6
Cones	3.2	3.4	36.4	30.0	12.6	6.3	3.6	3.2	1.2
Cowberry leaves	7.0	4.2	52.8	20.7	2.8	4.9	3.9	3.0	0.8
Heather litter	5.5	6.0	43.3	18.4	3.2	14.3	4.9	3.3	1.2
Moss litter	8.6	1.4	41.7	22.1	9.4	4.2	6.6	3.6	2.5
Miscellaneous	4.6	6.1	44.8	21.9	9.5	3.7	6.2	2.1	1.2
Lichens	4.2	1.2	6.4	29.5	35.4	0.4	21.7	0.6	0.7
FH layer									
Ashfree fraction	4.2	3.7	22.0	20.9	4.2	3.1	3.3	1.5	0.9

Table 11. Total amounts of some organic compounds in the L and FH layers at Ih VA. All figures are given in g/m^2. Sampling in September 1975 (S2)

	Water soluble	Acetone soluble	Klason lignin	Cellulose	Mannan	Xylan	Galactan	Araban	Rhamnan
L layer									
Needles	10.7	13.4	55.9	40.1	11.5	4.9	5.5	4.8	2.4
Bark	2.8	1.9	26.4	13.3	2.5	4.1	3.4	4.2	0.4
Pine twigs									
>5 mm Ø	0.4	0.5	4.0	2.4	0.4	0.6	0.5	0.2	0.0
<5 mm Ø	1.1	1.8	11.1	5.7	1.7	1.6	1.3	0.8	0.2
Cones	1.4	1.5	16.4	13.5	5.7	2.8	1.6	1.4	0.5
Cowberry leaves	2.1	1.3	15.8	6.2	0.8	1.5	1.2	0.9	0.2
Heather litter	30.3	3.3	23.8	5.5	1.0	4.3	1.5	1.0	0.4
Moss litter	7.4	1.2	35.9	19.0	8.1	3.6	5.7	3.1	2.2
Miscellaneous	11.9	15.8	116.0	56.7	24.6	9.6	16.1	5.4	3.1
Total L layer	68.1	40.7	305.3	162.4	56.3	33.0	36.8	21.8	9.4
FH layer									
Total	64.7	57.0	338.8	321.9	64.7	47.7	50.8	23.1	13.9

Table 12. Standard error of mean, expressed as per cent of the mean, for weights and elemental concentrations of needle litter from Ih VA. Calculations for both the original sample set and the composite samples are given. Sampling: May 1974 (S1)

	Individual samples (n=15)		Composite samples (n=5)	
	standard error in % of concentrations	amounts per sample	standard error in % of concentrations	amounts per sample
Dry weight		4.74		5.50
C	0.24	4.73	0.28	5.44
N	2.99	5.36	3.47	7.18
P	4.28	5.32	4.97	6.61
K	4.76	6.73	5.52	9.19
Na	3.74	6.39	4.34	6.08
Ca	2.88	5.08	3.34	6.12
Mg	4.02	5.19	4.66	3.87

Table 13. Standard errors of mean, expressed as per cent of the mean, for weights and elemental concentrations of different litter types from the L layer of Ih VA. Calculations for the composite samples are given (n=5). Sampling: September 1975.

	Dry weight	C	N	P	K	Na	Ca	Mg	S
Needles	11.2	0.3	3.8	2.0	5.3	4.8	6.3	6.1	5.7
Bark	9.0	0.2	3.3	4.6	9.5	3.8	3.2	5.1	2.7
Pine twigs > 5 mm Ø	15.1	0.9	6.5	6.1	13.3	23.0	11.6	10.7	14.9
Pine twigs < 5 mm Ø	12.7	0.7	5.8	6.4	13.6	8.4	12.4	11.2	6.4
Cones	16.0	-	-	-	-	-	-	-	-
Cowberry leaves	12.9	0.4	6.2	4.0	6.7	8.9	2.6	3.5	6.9
Heather litter	14.3	0.9	4.5	3.8	6.8	14.3	7.6	5.9	3.0
Moss litter	12.5	0.2	6.9	9.6	9.1	4.0	11.1	3.9	7.9
Miscellaneous	9.7	0.3	2.7	6.6	8.2	8.1	7.4	7.9	6.3

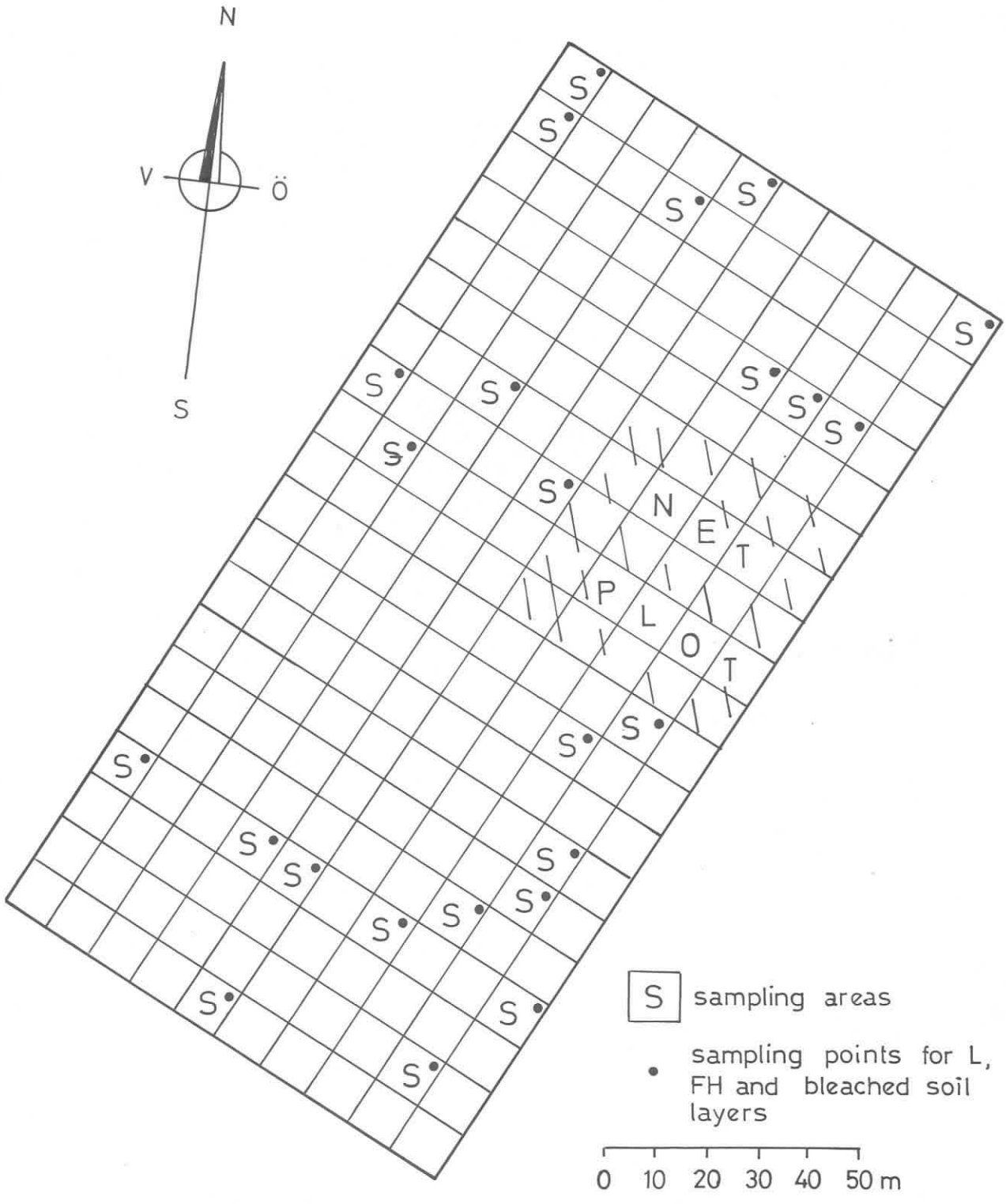

Figure 1. Map of Ih VA with sampling areas for the L, FH and mineral soil layers indicated. In the May sampling (S1) only fifteen of these areas were used.

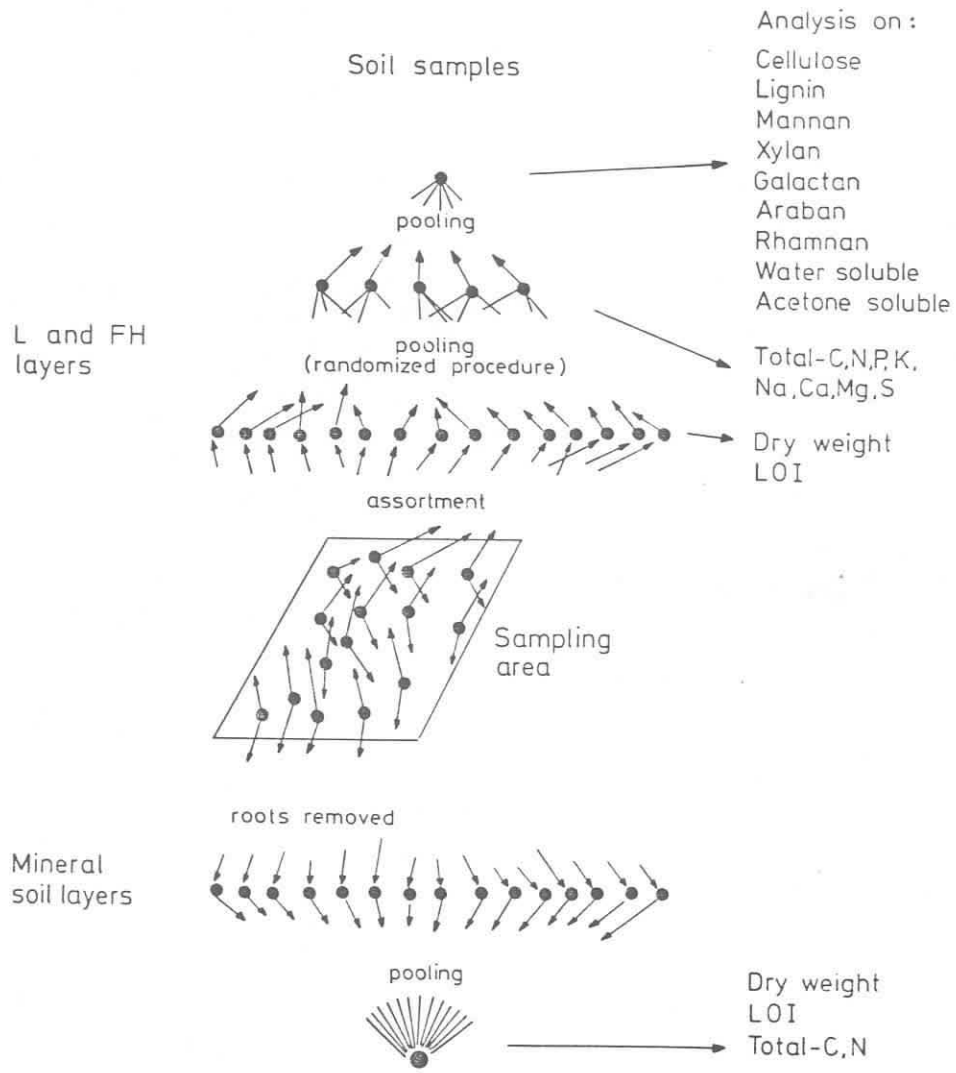

Figure 2. Outline of the treatment and analysis of the May sampling (S1). The same pattern was used for the September sampling (S2). After sampling in the field the L and FH layer samples were assorted into litter components and weighed individually. The loss on ignition was determined. Thereafter the samples were randomly pooled to composite samples and carbon, nitrogen, phosphorus, sodium, calcium and magnesium were determined. Organic analysis was carried out on one sample pooled from the composite samples. Roots were removed from the mineral soil samples which thereafter were pooled to one sample and dry weight, loss on ignition, carbon and nitrogen were determined.

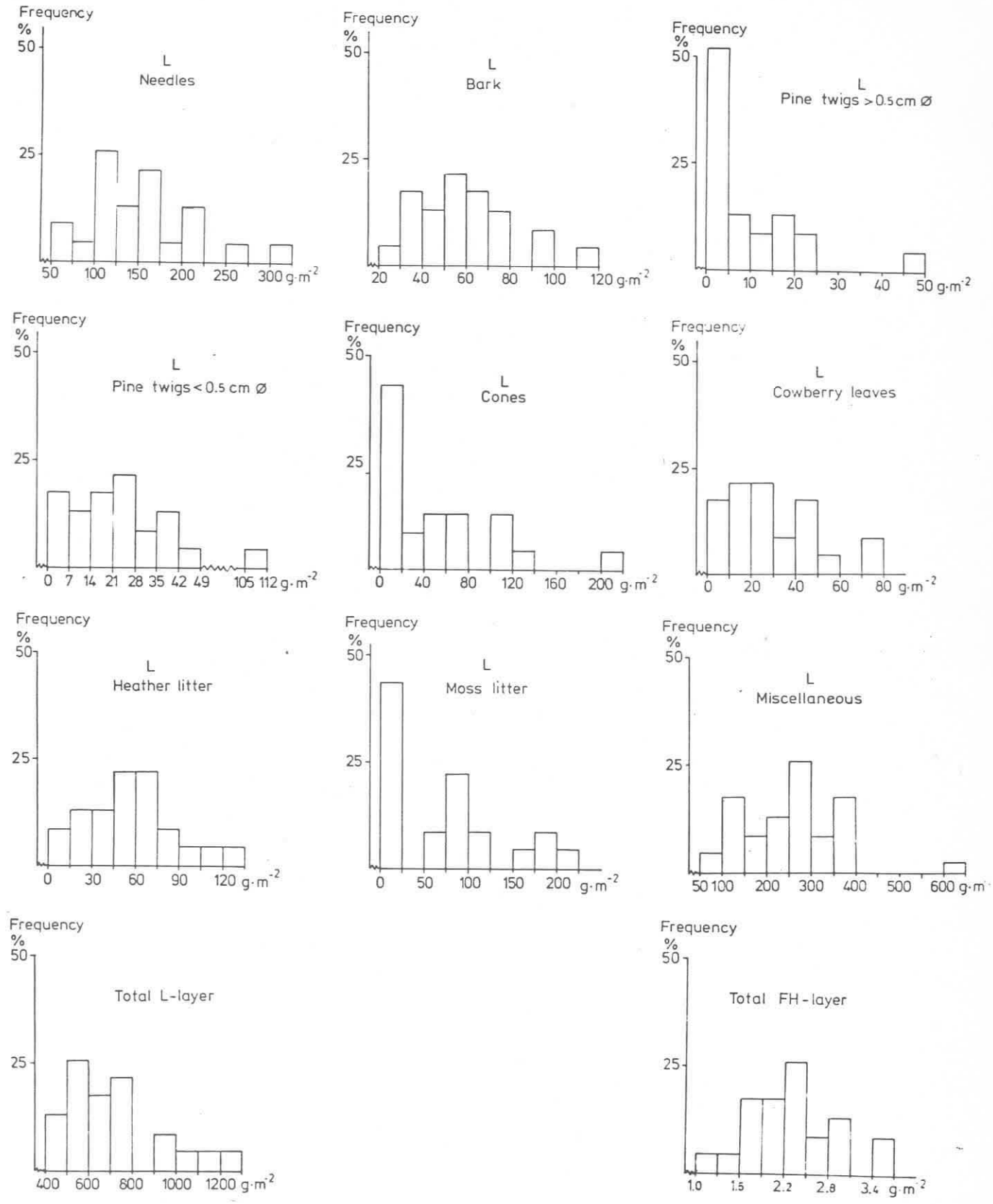

Figure 3. The frequency distribution of weights of L layer litter components and total L and FH soil layers from Ih VA. Sampling in September 1975 (S2).